8 Cardiovascular System

8.1 Objectives

After completing this section, you should know:

- the main functions of blood
- what the term haematocrit or packed cell volume (PCV) means
- what is in blood
- what plasma is and what is in it
- the appearance and function of red blood cells (RBCs)
- the appearance and function of white blood cells particularly granulocytes, lymphocytes and
- monocytes
- the function of platelets and fibrinogen in blood clotting
- how oxygen and carbon dioxide are transported in the blood
- the names of some anticoagulants and their function in the body and in the vet clinic

- where the heart is located in the body
- the structure of the heart
- the structure and function of the heart valves and their role in producing the heart sounds
- the stages of the heart beat and the route the blood takes through the heart
- that the coronary arteries supply the heart muscle

- that the circulatory system is double consisting of pulmonary and systemic circuits with the blood passing through the heart twice;
- the differences in the structure and function of arteries, capillaries and veins;
- how the pulse is produced and where it can be felt;
- what tissue fluid and lymph are and how they are formed;
- the names of the main arteries and veins.

8.2 Blood

Blood is a unique fluid containing cells that is pumped by the heart around the body of animals in a system of pipes known as the circulatory system. It carries oxygen and nutrients to the cells of the body and removes waste products like carbon dioxide from them. Blood is also important for keeping conditions in the body constant, in other words for maintaining homeostasis. It helps keep the acidity or pH stable and helps maintain a constant temperature in the body. Blood also has an important role in defending the body against disease (an important role in immunity).

A simple way to find out what is in blood is to remove a small amount from an animal and place it in a tube with a substance that prevents it from clotting (an anticoagulant). If you leave the tube to stand for a few hours you will find that it settles out into two layers. The top layer consists of a light yellow fluid, the plasma, and the bottom layer consists of red blood cells (RBCs). If you look very carefully you can also see a thin beige-coloured layer in between these two layers. This consists of the white blood cells (WBCs) (see diagram 8.1).

The above procedure is usually done more rapidly by placing the blood sample in a centrifuge for a few minutes. This machine acts like a super spin drier rotating about 10,000 times a minute and packing the heavier particles (red blood cells) at the bottom of the tube. The sample that results is called the packed cell volume (P.C.V.) or haematocrit. It is a very useful measurement of the concentration of red blood cells in the blood. For most animals the packed cell volume is in the range 30-45%. If it is lower than this it means that the concentration of red blood cells is low and the animal is anaemic. If the reading is above this range it may mean the animal is dehydrated. Animals that live at high altitudes also have high P.C.V.s to compensate for the low oxygen concentration there.

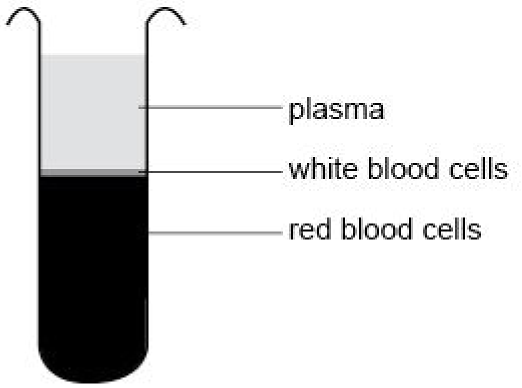

Diagram 8.1 - Packed cell volume of blood

8.2.1 Plasma

Plasma consists of water (91%) in which many substances are dissolved. These dissolved substances include:

- salts (or electrolytes)
- proteins
- nutrients
- waste products
- dissolved gases (mainly carbon dioxide)
- and other chemicals like hormones

8.2.2 Salts in Plasma

Salts in the plasma are in the form of ions or electrolytes which include sodium, potassium, calcium, chloride, phosphate and bicarbonate. Plasma transports these ions to where they are needed e.g. calcium required by the bones, they also help keep the osmotic pressure and acid-base balance (pH) of the blood within the required levels.

8.2.3 Blood Proteins

The proteins in the blood plasma are large molecules with important functions. Some contribute to the osmotic pressure (see chapter 3) and the viscosity (thickness) of the blood, and so help keep the blood volume and pressure stable. Others act as antibodies that attack bacteria and viruses, and yet others are important in blood clotting. Nutrients that are absorbed from the gut and transported to the cells in the plasma include amino acids, glucose, fatty acids and vitamins. Waste products include urea from the breakdown of proteins.

8.2.4 Red Blood Cells

Red blood cells are also known as RBCs or erythrocytes. They are what make blood red. When you look at a blood smear through a microscope, as you will in one of the practical classes, you will see that RBCs are by far the most common cells in the blood. (In fact there are about 5 million per millilitre). If you focus on an individual RBC you will see that they are shaped like discs or doughnuts with a thin central portion surrounded by a fatter margin. This shape has all sorts of advantages, one being that enables the cells to fold up and pass along the narrowest blood capillaries (See diagram 8.2).

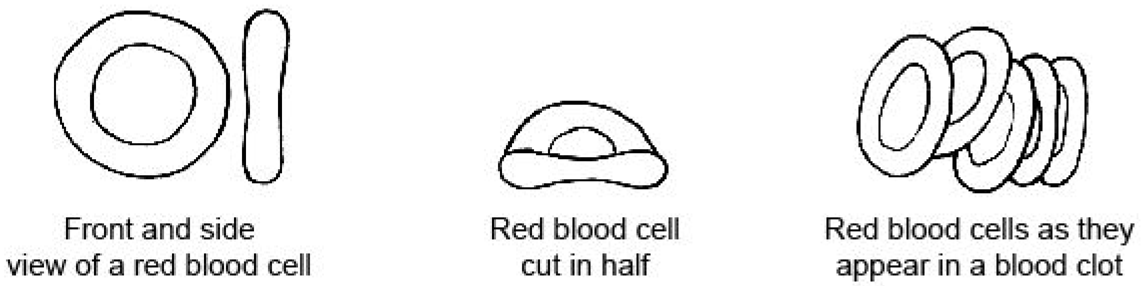

Diagram 8.2 - Red blood cells or erythrocytes

The mature RBCs of mammals have neither nucleus nor other organelles and can be thought of as sacks of haemoglobin. Haemoglobin is a red coloured protein containing iron, which joins with oxygen so the blood can transport it to body cells. RBCs are made continuously in the bone marrow and live about 120 days. They are then destroyed in the liver and spleen and the molecules they are made from recycled to make new RBCs. Anaemia results if the rate at which RBCs are destroyed exceeds the rate at which RBC'c are 'produced'.

Note that if you happen to look at bird's, reptiles, frogs or fishes blood down the microscope you will see that these vertebrates all have RBCs with a central nucleus.

8.2.5 White Blood Cells

White blood cells or leukocytes are far less numerous than red blood cells. In fact there is only about one white cell for every 1000 red blood cells. Rather than being white, they are actually colourless as they contain no hemoglobin although unlike RBCs they do have a nucleus. If you make a blood smear and look at it under the microscope it is difficult to see the white blood cells at all. To make them visible you need to stain them with special dyes or stains. There are a variety of stains that can be used, but most dye the nucleus a dark purple or pink colour. The stains may also show up the granules present in the cytoplasm of some white blood cells. White blood cells are divided into two major groups depending on the shape of the nucleus and whether or not there are granules in the cytoplasm.

1. Granulocytes or polymorphonuclear leucocytes ("polymorphs" or "polys") have granules in the cytoplasm and a purple lobed nucleus (see diagram 8.3). The most common (neutrophils) can squeeze out of capillaries and are involved in engulfing and destroying foreign invaders like bacteria (see diagram 8.4). Some (eosinophils) combat allergies and increase in numbers during parasitic worm infections. Others (basophils) produce heparin that prevents the blood from clotting.

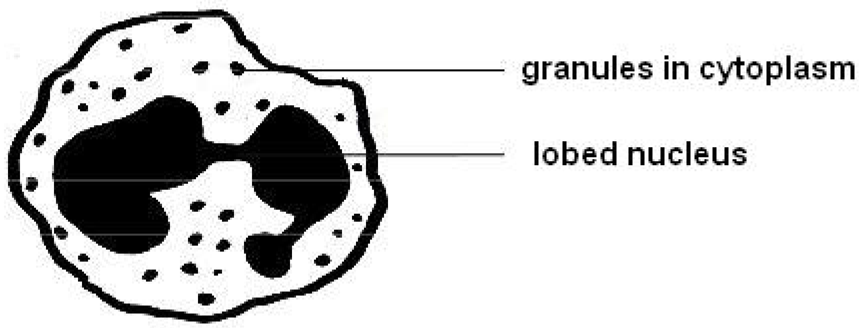

Diagram 8.3 - A granulocyte

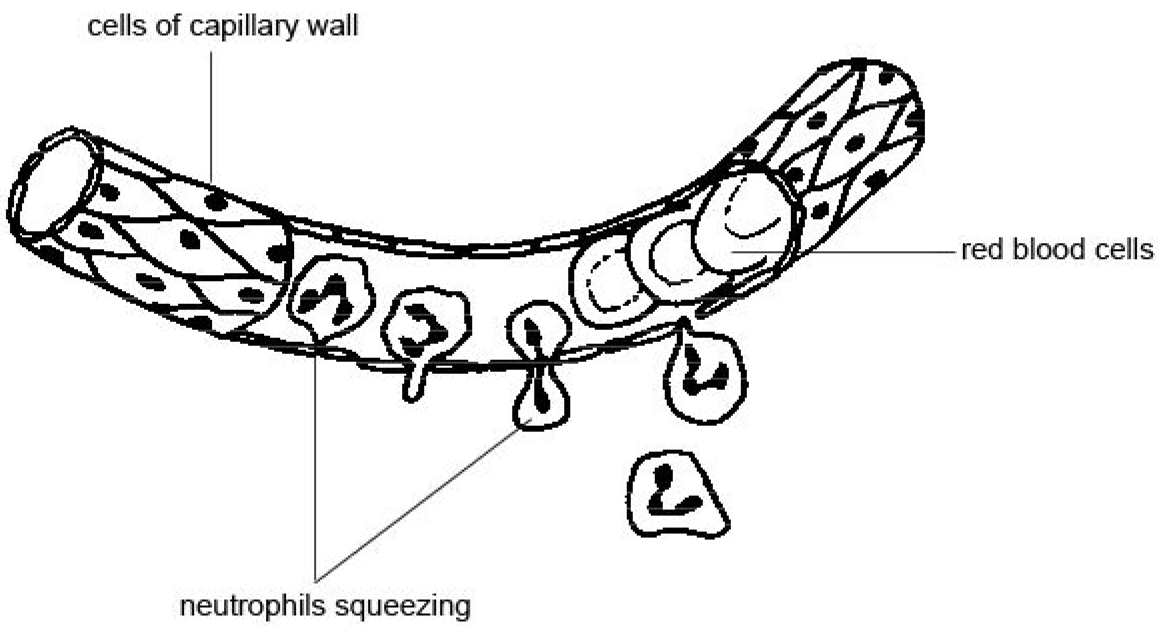

Diagram 8.4 - Neutrophils escaping from a capillary

2. Agranulocytes or monomorphonuclear leucocytes have a large unlobed nucleus and no granules in the cytoplasm. There are two types of agranulocytes. The most numerous are lymphocytes that are concerned with immune responses. The second type is the monocyte that is the largest blood cell and is involved in engulfing bacteria etc. by phagocytosis (see diagram 8.5).

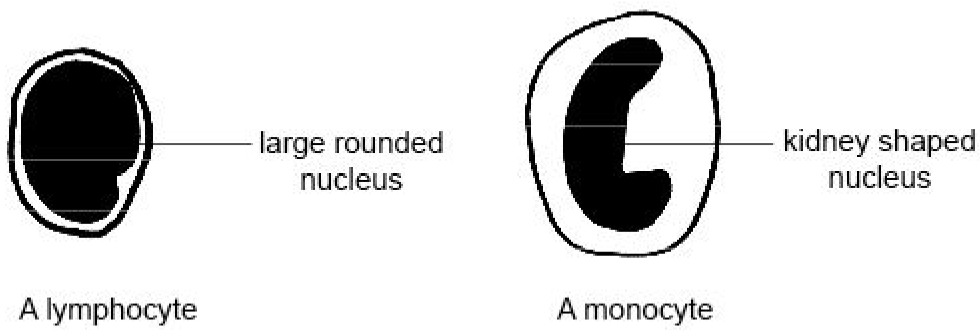

Diagram 8.5 - Agranular leucocytes

8.2.6 Platelets

As well as red and white blood cells, the blood also contains small irregular shaped fragments of cells known as platelets. They are involved in the clotting of the blood (see later).

8.2.7 Transport Of Oxygen

The purpose of the haemoglobin in red blood cells is to carry oxygen from the lungs to the tissues. In fact it allows the blood to carry about 25 times more oxygen than it would be able to without any haemoglobin.

When oxygen concentrations are high, as in the blood capillaries in the lungs, haemoglobin combines with oxygen to form a compound called oxyhaemoglobin. This compound is bright red and makes the oxygenated blood that spurts from a damaged artery its characteristic bright red colour. When the blood reaches the tissues where the oxygen concentrations are low, the oxygen separates from the haemoglobin and diffuses into the tissues. The haemoglobin in most veins has given up its oxygen and the blood is called deoxygenated blood. It is a purple-red colour.

8.2.8 Carbon Monoxide Poisoning

Carbon monoxide is a colourless, odourless gas found in car exhaust fumes and tobacco smoke. It combines with haemoglobin just like oxygen but does not let go. This means the haemoglobin molecules are not available to carry oxygen to the tissues and the animal or human suffocates. Carbon monoxide poisoning is often fatal but can be treated by giving the patient pure oxygen that slowly replaces the carbon monoxide. This could be conceived numerically as a probability issue: carbon monoxide binds 200 times stronger than oxygen to the iron atom in haemaglobin , but this bond I has dynamic states where the CO molecule moves away temporarily from the iron atom and then it depends on chances of an oxygen atom being near enough to the iron atom to takeover the electrostatic bond. If there are enough oxygen molecules around, the carbon monoxide molecule is crowded out and moved further away from the iron atom , enough to overcome the 200 times attractivity of carbon monoxide to the iron moiety.

8.2.9 Transport Of Carbon Dioxide

Carbon dioxide is a waste gas produced by cells. It diffuses into the blood capillaries where it is carried to the lungs in the blood. Most is carried in the plasma as bicarbonate ions but a small amount is dissolved directly in the plasma and some combines with haemoglobin.

8.2.10 Transport Of Other Substances

The blood carries water to the cells and organs as well as soluble food substances (sugars, amino acids, fatty acids and vitamins) and hormones dissolved in the plasma. These are delivered to the cells via the tissue fluid (see later in this chapter) that surrounds them. Blood also picks up the waste products like carbon dioxide and urea from the cells and is important in distributing the heat produced in the liver and muscles all over the body.

8.2.11 Blood Clotting

The mechanism that causes the blood to clot is easily seen when you or your animals are injured. However, minor injuries occur all the time in areas that experience wear and tear like the intestine, the lungs and the skin. Without the clotting mechanism, animals would quickly bleed to death from minor injury and internal haemorrhage. This is what happens in animals and people with clotting disorders like haemophilia, as well as animals that are poisoned with rat poisons like warfarin.

Platelets are important in blood clotting. When blood vessels are damaged, substances released cause the blood platelets to disintegrate. This stimulates a complex chain of reactions, which causes the protein fibrinogen to be converted to fibrin. Fibrin forms a dense fibrous network over the wound preventing the escape of further blood. Calcium and vitamin K are essential for the clotting process and any deficiency of these may also lead to clotting problems.

8.2.12 Serum And Plasma

When blood clots it separates into the clot that contains most of the cells and platelets leaving behind a straw coloured fluid. This fluid is called serum. It looks just like plasma and is similar in composition except for one big difference. It doesn't contain fibrinogen, the protein that forms the clot.

8.2.13 Anticoagulants

Anticoagulants are substances that interfere with the clotting process. When blood is collected for transfusion or testing it is often important to prevent it clotting and there are a number of different anticoagulants you can use for this. Tubes containing the different anticoagulants are coded with different colours for easy recognition.

- **Heparin** (colour code - green) is a natural anticoagulant produced by the white blood cells but it is also used routinely in the laboratory with samples to be tested for heavy metals like lead.
- **EDTA** (colour code – lavender) is used for routine blood counts.
- **Fluoroxylate** (colour code – grey) is used for biochemical tests for glucose.
- **Citrate** (colour code – light blue) is used for the storage of large quantities of blood, such as used in transfusions.

8.2.14 Haemolysis

Haemolysis is the breakdown of the plasma membrane of red blood cells to release the haemoglobin. We have already met this process when discussing osmosis, for haemolysis often occurs when red blood cells are placed in a hypotonic solution and water flows in through the semi permeable plasma membrane to swell and eventually burst the cell. It is therefore important when collecting blood from an animal to make sure there is no water in the syringe or tube. Too much movement due to shaking the tube or sucking up the blood too vigorously can also break down the plasma membrane and cause haemolysis.

8.2.15 Blood Groups

If you have given blood recently you may know your blood group. It may be blood group O, A or B or even AB, the rarest group. Blood groups are the result of different molecules called antigens on the outside of red blood cells. These cause antibodies to be formed that attack viruses and bacteria. Knowledge of a person's blood group is important when giving transfusions because if blood of another incompatible blood group is given to a patient the red blood cells stick together and block the blood vessels and may lead to death.

Blood groups also exist in many animals. There are three blood groups in cats and great care has to be taken that the groups are compatible when transfusing exotic breeds. The situation is slightly different in dogs. They have a number of blood groups but there is usually no problem with the first blood transfusion a dog receives. However, this first transfusion sensitises the immune system so that a problem may arise with the second and subsequent transfusions.

Haemolysis can occur in the living animal when it is exposed to various poisons and toxins. This may happen when, for example, it eats a poisonous plant, is bitten by a snake or infected with bacteria that destroy red blood cells (haemolytic bacteria).

8.2.16 Blood Volume

Blood accounts for between 6-10% of the body weight of animals, varying with the species and the stage of life. Animals can not tolerate losses of greater than 3% of the total volume when the condition known as shock occurs.

8.2.17 Summary Blood

- The main functions of blood are transport of oxygen, food, waste products etc., the maintenance of homeostasis and defending the body from disease.
- Blood consists of fluid, plasma, in which red and white blood cells are suspended. The blood cells typically make up 30-45% of the blood volume.
- Plasma consists of water containing dissolved substances like proteins, nutrients and carbon dioxide.
- Red Blood Cells contain **haemoglobin** to transport **oxygen**.
- **White Blood Cells** defend the body from invasion. There are 2 kinds:
- Granular white cells include **neutrophils**, **basophils** and **eosinophils**. Neutrophils which destroy bacteria are the most numerous. Eosinophils are involved with allergies and parasitic infections.

- **Non-granular white cells** include **lymphocytes** that produce antibodies to attack bacteria and viruses and monocytes that engulf and destroy bacteria and viruses.
- **Platelets** are involved in blood clotting.

8.3 The Heart

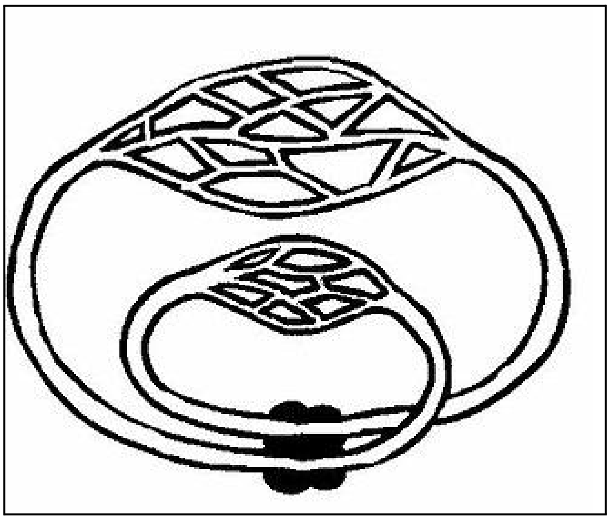

Diagram 8.6: The double closed circulation of a mammal

The heart is the pump that pushes the blood around the body in the blood vessels of the **circulatory system**. In fish the blood only passes through the heart once on its way to the gills and then round the rest of the body. However, in mammals and birds that have lungs, the blood passes through the heart twice: once on its way to the lungs where it picks up oxygen and then through the heart again to be pumped all over the body. The heart is therefore two separate pumps, side by side (see diagram 8.6).

The heart is situated in the thorax between the lungs and is protected by the rib cage. In some animals it is displaced slightly to the left-hand side. A tough membrane called the **pericardium** covers it. There is a narrow space between the pericardium and the heart that is filled with a liquid that acts as a lubricant.

The heart of mammals is a hollow bag made of cardiac muscle (see chapter 4). The cavity inside the heart is divided into 4 chambers. The chambers on the right side are completely separate from the chambers on the left side. The two upper chambers are thin walled, and are called the **atria** (or auricles). The two lower chambers are thick walled and are called the **ventricles** (see diagrams 8.7 and 8.8).

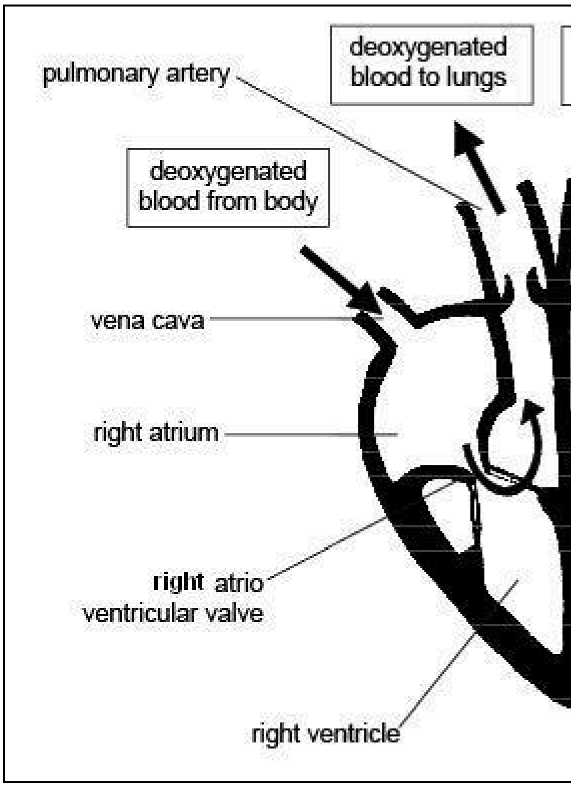

Diagram 8.7: Simplified diagram of the internal structure of the mammalian heart

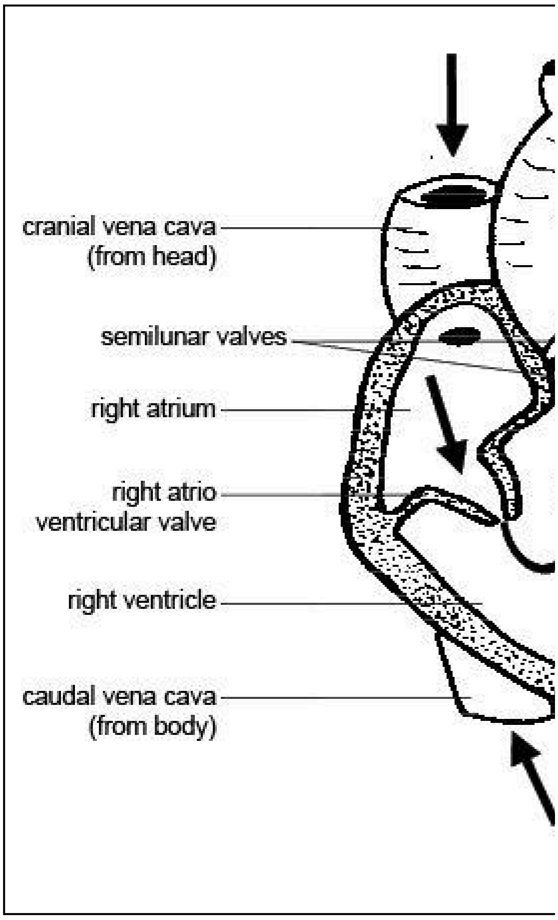

Diagram 8.8: The internal structure and blood flow through the heart

8.3.1 The Heart

Blood flows through the heart in a one way system. The right atrium receives deoxygenated blood from the body via the largest vein in the body called the **vena cava**. The contraction of the atrium pumps the blood into the right ventricle and then into the lungs via the **pulmonary artery**. The blood is oxygenated in the lungs and then returns to the heart and enters the left atrium via the **pulmonary vein**. The contraction of the left atrium pumps the blood into the left ventricle, which then pumps it to the body via the **aorta** (see diagrams 8.7 and 8.8). The wall of the left ventricle is usually much thicker than that of the right ventricle because it has to pump the blood to the end of the digits and tip of the tail while the right ventricle only has to pump the blood to the nearby lungs.

8.3.2 Valves

Valves are flaps of tissue that stop blood flowing backwards and so control the direction of blood flow in the heart. There are two kinds of valves in the heart. The first kind is the massive valves between the atria and the ventricles, the

atrio-ventricular valves, (AV valves) that prevent blood in the ventricles from flowing back into the atria. The flaps of these valves are attached to the walls of the ventricles by tendons. These make them look somewhat like parachutes (see diagram 8.9).

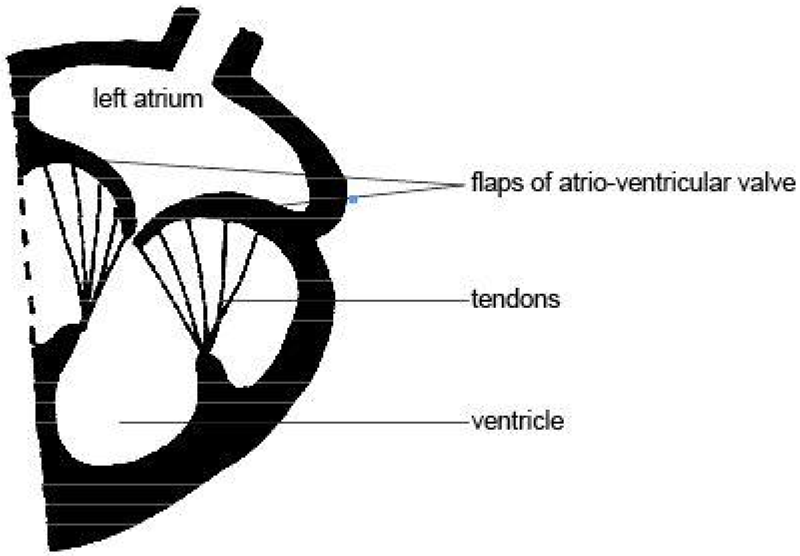

Diagram 8.9 - The atrio-ventricular or parachute valves

The second kind of valve is pocket shaped flaps of tissue called the **semilunar** (half moon) **valves** (see diagram 8). They are called the **pulmonary and aortic valves** and found at the back of the pulmonary artery and aorta respectively.

8.3.3 The Heartbeat

The heartbeat consists of alternating contractions and relaxations of the heart. If you listen to the heart with a stethoscope, you hear the sounds often described as "**lub-dub**".

There are four stages to each heartbeat:

1. Each atrium relaxes so that blood can enter. Blood flows from the body via the vena cava into the right atrium. At the same time, blood flows from the lungs via the pulmonary vein into the left atrium (see diagram 8.10a).
2. The atrioventricular valves open and both ventricles relax. The atria contracts and blood flows from the right atrium into the right ventricle and from the left atrium into the left ventricle (see diagram 8.10b).
3. The ventricles contract and the atrioventricular valves snap shut to stop blood flowing back into the atria. This is the first sound ("lub")

of the heartbeat that can be heard with a stethoscope (see diagram 8.10c).

4. The semi-lunar valves open and blood is pumped out of the right ventricle to the lungs. At the same time, blood is pumped out of the left ventricle into the aorta and so to the rest of the body. When the ventricles stop contracting, the semi-lunar valves snap shut to stop blood flowing backward.

This is the second sound (“dub”) of the heartbeat. Blood flows into the atria again as they relax and the cycle is repeated.

When a valve is damaged and fails to close completely, some blood may flow backward after each heartbeat. A trained veterinarian hears this with a stethoscope as a “**heart murmur**”.

The period of the heartbeat when the ventricles are contracting and sending a wave of blood down the pulmonary artery and aorta is called **systole**. The period when the ventricles are relaxing is called **diastole**.

8.3.4 Cardiac Muscle

The walls of the heart consist of cardiac muscle, a special kind of muscle only found in the heart. The cells of cardiac muscle form a branching network of separating and rejoining fibres which allows nerve impulses to travel through the tissue (see Chapter 7). Heart muscle needs lots of energy to function so it is well supplied with mitochondria and requires a good supply of oxygen. This is provided by the coronary arteries (see below).

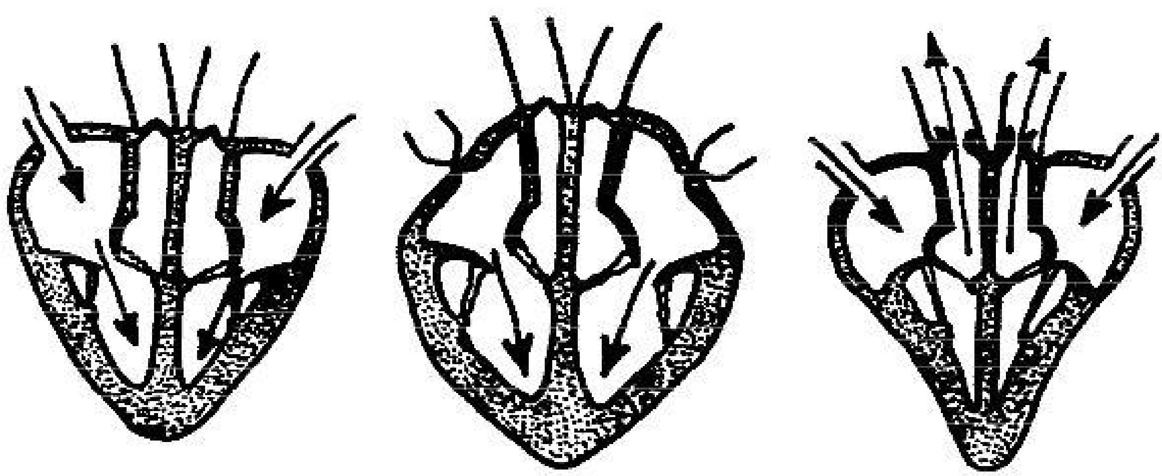

Diagram 8.10 a) First stage of heartbeat b) Second stage of heartbeat c) Third stage of heartbeat

8.3.5 Control Of The Heartbeat

The cardiac muscle of the walls of the heart contracts of its own accord. This can be demonstrated by the rather macabre experiment in which a small portion of heart muscle is removed and placed in a solution that is similar to blood. The tissue will continue to contract and relax for a time. In the normal functioning heart the **pacemaker** acts rather like the conductor of an orchestra and superimposes a unified beat upon the heart as a whole. The pacemaker is situated in the wall of the right atrium. The rate at which the heart beats is modified by a part of the brain called the **medulla oblongata** (see Chapter 14) and by the hormone adrenalin (see Chapter 16) which speeds up the heartbeat.

8.3.6 The Coronary Vessels

Although oxygenated blood passes through some of the chambers of the heart it can not supply the muscle of the heart walls with the oxygen and nutrients it needs. Special arteries called the **coronary arteries** do this. These two arteries arise from the aorta and branch through the heart to deliver oxygen and nutrients to the cardiac muscles and collect carbon dioxide and wastes. Coronary veins return the blood to right hand side of the heart. Some of these vessels can be seen on the outside surface of the heart (see diagram 8.11). Sometimes fatty deposits on the inside wall of the coronary artery block the blood flow to the heart muscle. If the obstruction is severe enough to damage the heart muscle due to inadequate blood supply a “heart attack” can result.

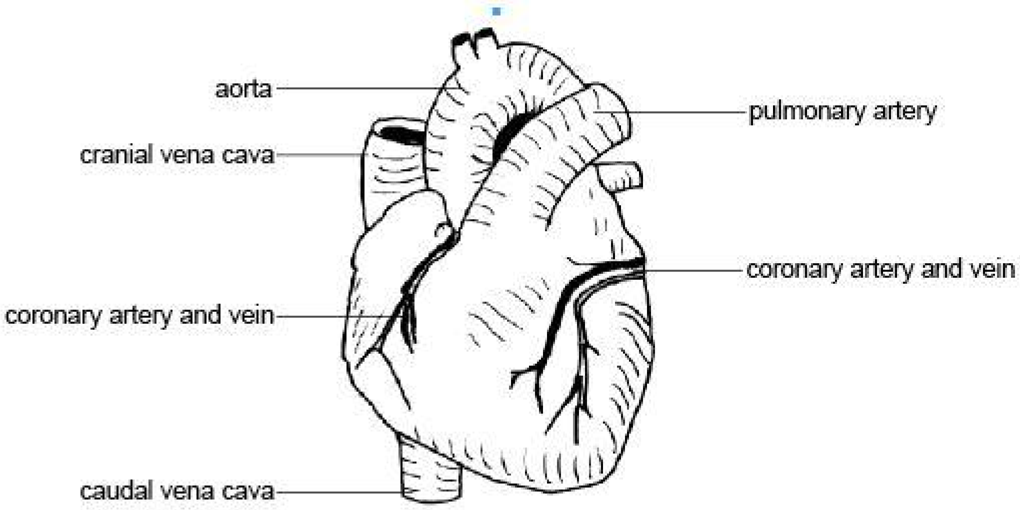

Diagram 8.11 - The heart showing coronary vessels

8.3.7 Summary

- The heart is situated in the thorax between the lungs

- The heart is a hollow bag made of **cardiac muscle**. It is divided into four chambers (right and left atria and right and left ventricles).
- Valves stop blood flowing backwards. The right and left **atrio-ventricular valves** prevent blood in the ventricles from flowing back into the atria. The **semilunar valves** at the entrance of the pulmonary artery and aorta prevent blood flowing back into the ventricles. The closing of the valves produces the heart sounds heard with a stethoscope.
- There are 4 stages to the heart beat. 1. blood flows into the right and left atria. 2. The atria contract and blood flows into the ventricles. 3. The ventricles contract and the closing of the atrio-ventricular valves produces the first heart sound. 4. Blood flows to the lungs and body and when the ventricles stop contracting the closing of the semilunar valves produces the second heart sound.
- The **coronary arteries** supply the heart muscle with oxygenated blood.

8.4 Blood circulation

8.4.1 Blood Circulation

The circulatory system is the continuous system of tubes through which the blood is pumped around the body. It supplies the tissues with their requirements and removes waste products. In mammals and birds the blood circulates through two separate systems - the first from the heart to the lungs and back to the heart again (the pulmonary circulation) and the second from the heart to the head and body and back again (the systemic circulation) (see diagram 8.12).

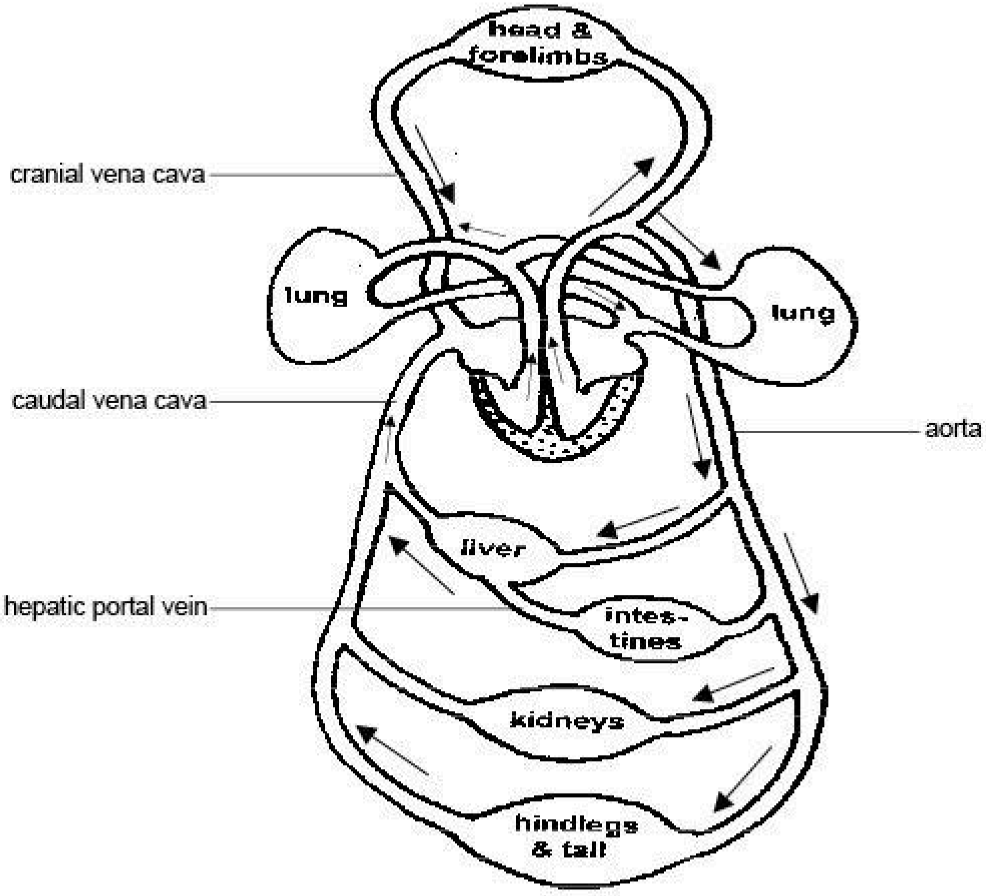

Diagram 8.12 - The mammalian circulatory system

The tubes through which the blood flows are the **arteries, capillaries** and **veins**. The heart pumps blood into arteries that carry it away from the heart. The arteries divide into very thin vessels called capillaries that form a network between the cells of the body. The capillaries then join up again to make veins that return the blood to the heart.

8.4.2 Arteries

Arteries carry blood away from the heart. They have thick elastic walls that stretch and can withstand the surges of high pressure blood caused by the heartbeat (the pulse, see later). The arteries divide into smaller vessels called **arterioles**. The hole down the centre of the artery is called the **lumen**. There are three layers of tissue in the walls of an artery. It is lined with squamous epithelial cells. The middle layer is the thickest layer. It made of elastic fibres and smooth muscle to make it stretchy. The outer fibrous layer protects the artery (see diagram 8.13). The **pulse** is only felt in arteries.

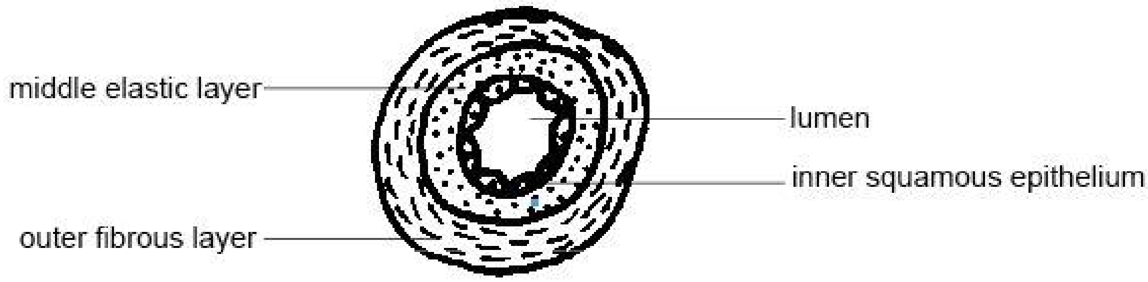

Diagram 8.13 - Cross section of an artery

The Pulse

The pulse is the spurt of high pressure blood that passes along the aorta and arteries when the left ventricle contracts. As the pulse of blood passes along an artery the elastic walls stretch. When the pulse has passed the walls contract and this helps push the blood along. The pulse is easily felt at certain places where an artery passes near the surface of the body. It is strongest near the heart and becomes weaker as it travels away from the heart. The pulse disappears altogether in the capillaries.

8.4.3 Capillaries

Arterioles divide repeatedly to form a network penetrating between the cells of all tissues of the body. These small vessels are called capillaries. The walls are only one cell thick and some capillaries are so narrow that red blood cells have to fold up to pass through them. Capillaries form networks in tissues called capillary beds. The capillary networks in capillary beds are so dense that no living cell is far from its supply of oxygen and food (see diagram 8.14).

Note: All arteries carry oxygenated blood except for the pulmonary artery that carries deoxygenated blood to the lungs.

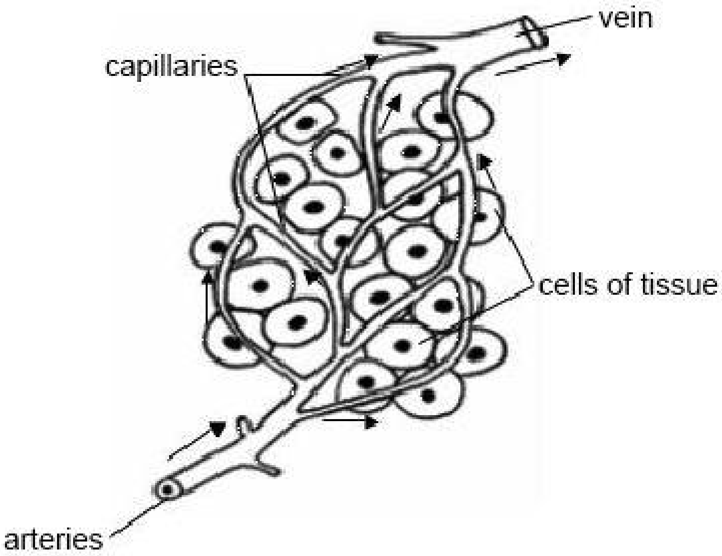

Diagram 8.14 - A capillary bed

8.4.4 The Formation Of Tissue Fluid And Lymph

The thin walls of capillaries allow water, some white blood cells and many dissolved substances to diffuse through them. These form a clear fluid called **tissue fluid** (or **extracellular fluid** or **interstitial fluid**) that surrounds the cells of the tissues. The tissue fluid allows oxygen and nutrients to pass from the blood to the cells and carbon dioxide and other waste products to be removed from the tissues (see diagram 8.15).

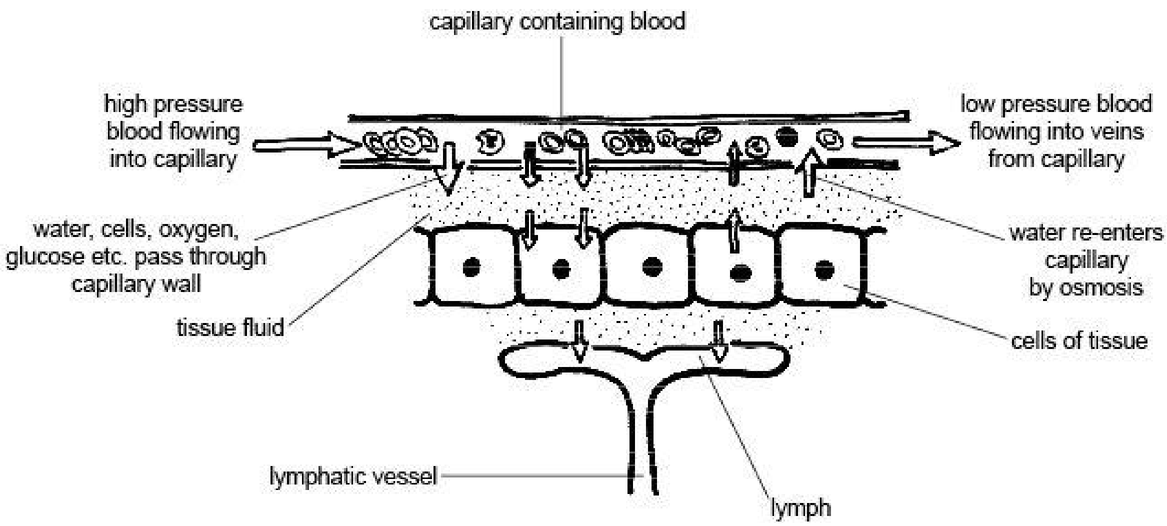

Diagram 8.15 - The formation of tissue fluid and lymph from blood

Some tissue fluid finds its way back into the capillaries and some of it flows into the blind-ended lymphatic vessels that form a network in the tissues. Once the tissue fluid has entered the lymphatics it is called **lymph** although its composition remains the same. The lymph vessels have walls that are even thinner than the capillaries. This means that molecules and particles that are larger than those that can pass into the blood stream e.g. cancer cells and bacteria can enter the lymphatic system. These are then filtered out as the lymph passes through lymph nodes. (See chapter 10 for more information on the lymphatic system).

8.4.5 Veins

Capillaries unite to form larger vessels called **venules** that join to form veins. Veins return blood to the heart and since blood that flows in veins has already passed through the fine capillaries, it flows slowly with no pulse and at low pressure. For this reason veins have thinner walls than arteries although they have the same three layers in them as arteries (see diagram 8.16). As there is no pulse in veins, the blood is squeezed along them by the contraction of the skeletal muscles that lay alongside them.

Veins also have **valves** in them that prevent blood flowing backwards (see diagram 8.17a and b).

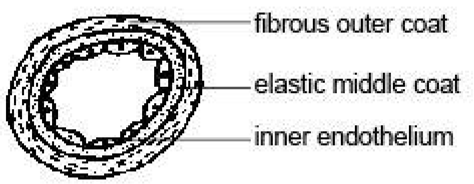

Diagram 8.16 - Cross section of a vein

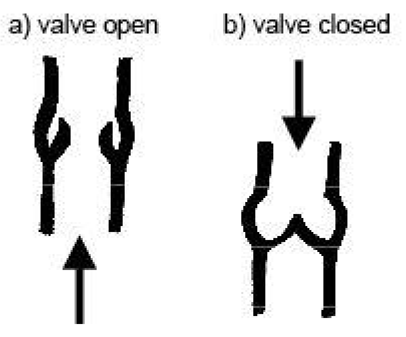

Diagram 8.17 a) and b) Valves in a vein

Note: Most veins carry deoxygenated blood. The pulmonary vein that carries oxygenated blood from the lungs to the left atrium of the heart is an exception.

8.4.6 Regulation Of Blood Flow

The flow of blood along arteries, arterioles and capillaries is not constant but can be controlled depending upon the requirements of the body. For example more blood is directed to the skeletal muscles, brain or digestive system when they are active. Regulation of the blood flow to the arterioles of the skin is also important in controlling body temperature. The size of the vessels is adjusted by the contraction or relaxation of smooth muscle fibres in their walls.

8.4.7 Oedema And Fluid Loss

Oedema is the swelling of the tissues due to the accumulation of tissue fluid. This may occur because the tissue fluid is prevented from returning to the bloodstream and accumulates in the tissues. This may be caused by physical inactivity (e.g. long car or plane trips in humans) or because of imbalances in the proteins in the blood. This is what causes the “pot-belly” of the malnourished child or worm-infested puppy.

Loss of body fluid can be caused not only by drinking insufficient liquid but also through diarrhea and vomiting or sudden loss of blood due to **haemorrhage.** The effect is to reduce the volume of the blood which decreases the blood pressure. This could be dangerous because the supply of adequate blood to the brain depends upon maintaining the blood pressure at a constant level.

To compensate for the loss of fluid various mechanisms come into play. First of all the blood vessels contract in order to try and maintain the pressure. Then, since the loss of fluid tends to make the blood more concentrated and increases its osmotic pressure, fluid is drawn into the blood from the tissues by osmosis.

8.4.8 The Spleen

The spleen is situated near the stomach. It has a rich blood supply and acts as a reservoir of red blood cells. When there is a sudden loss of blood, as happens when a haemorrhage occurs, the spleen contracts to release large numbers of red blood cells into the circulation. The spleen also destroys old red cells and makes new lymphocytes but it is not an essential organ because its removal in adult life seems to cause few problems.

8.4.9 Important Blood Vessels Of The Systemic (Body) Circulation

Blood is pumped out into the body via the main artery, the **aorta**. This takes the blood to the head, the limbs and all the body organs. After passing through a network of fine capillaries, the blood is returned to the heart in the largest vein, the **vena cava** (see diagrams 8.8, 8.12, 8.18 and 8.19).

Arteries and veins to and from many organs often run alongside each other and have the same name e.g. the **renal artery and vein** serve the kidney, the **femoral artery and vein** serve the hind limbs and the **subclavian artery and vein** serve the forelimbs. However, blood to the head passes along the **carotid artery** and returns to the cranial vena cava via the **jugular vein**.

One variation on this arrangement is found in the blood vessels that serve the digestive tract. A variety of arteries take blood from the aorta to the intestines but blood from the intestines is carried by the **hepatic portal vein** to the liver where the digested food can be processed (see diagram 8.12). This vessel is unlike others in that it transports blood from one organ to another rather precious Betine Diagram 8.18 - The main arteries and veins of the horse

8.4.10 Blood Pressure

The blood pressure is the pressure of the blood against the walls of the main arteries. The pressure is highest as the pulse produced by the contraction of the left ventricle passes along the artery. This is known as the **systolic pressure**. Pressure is much lower between pulses. This is known as the **diastolic pressure**. Blood pressure is measured in millimetres of mercury. A blood pressure that is higher than expected is known as **hypertension** while a pressure lower than expected is known as **hypotension.**

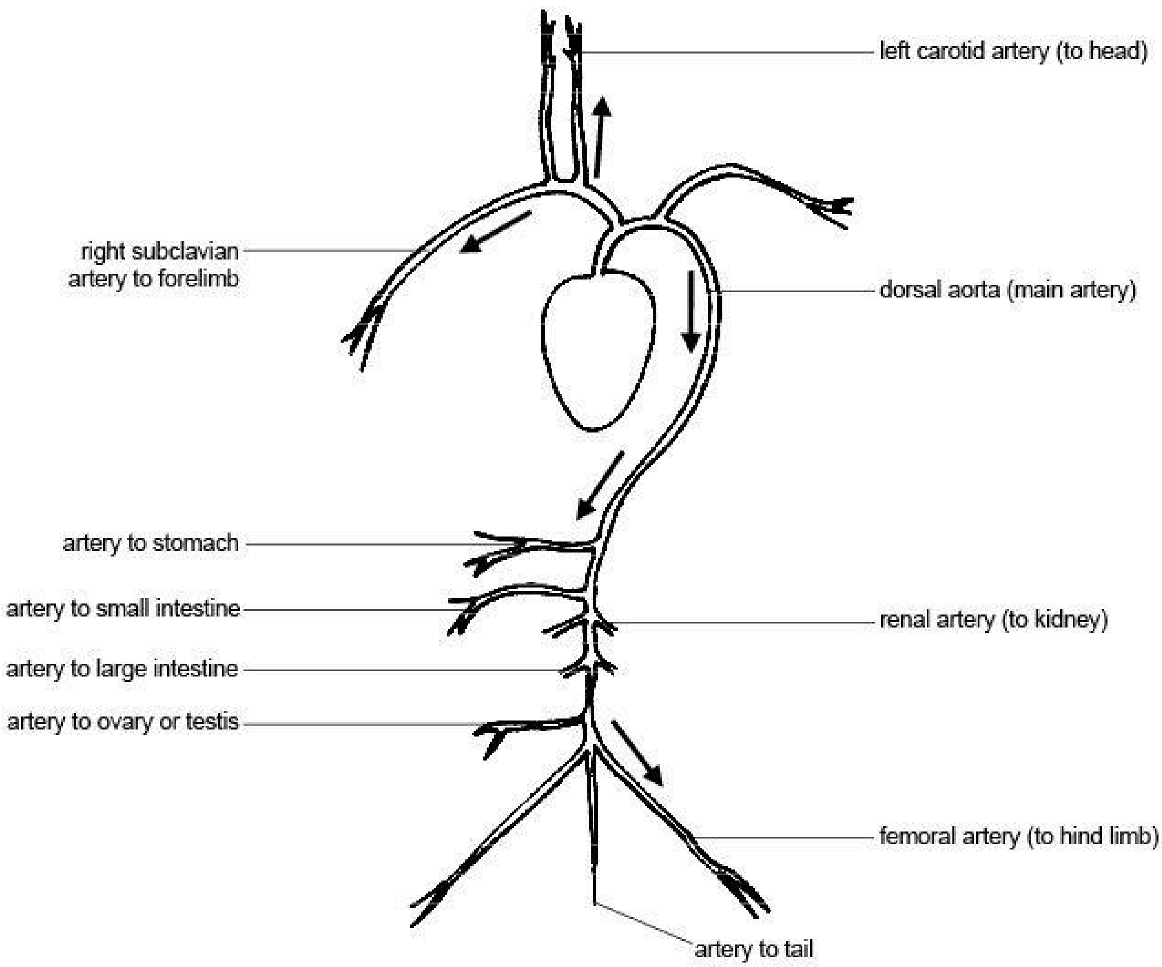

Diagram 8.19 - The main arteries of the body

8.4.11 Summary

- The circulatory system is double with the blood passing through the heart twice.
- **Arteries** carry blood away from the heart. They have thick elastic walls that stretch and can withstand the high pressure of the pulse.
- **Capillaries** are small, thin walled vessels that form a network between the cells of the tissues.
- **Veins** return low pressure blood to the heart. They have thinner walls than arteries.
- The **pulse** is the spurt of high pressure blood that passes along the arteries when the left ventricle contracts. It can be felt where arteries pass close to the body surface.
- **Tissue fluid** is the clear fluid that leaks from the capillaries and surrounds the cells of the tissues. **Lymph** forms when tissue fluid enters lymphatics.

- Important blood vessels include the vena cava, aorta, pulmonary artery, carotid

8.4 Worksheet

The exercises in the Blood Worksheet will help you learn how to identify the different types of blood cell and what their functions are.

This Circulatory System Worksheet will help you learn the main vessels of the circulatory system, the difference between arteries and veins, and what happens in a capillary bed.

Use the Heart Worksheet to help you learn the different parts of the heart, the role of the heart valves and how the heart beat pushes the blood through the heart.

8.5 Test Yourself

1. The liquid part of blood is known as:

2. There are two main types of cells in blood. They are:
    a.
    b.
3. The most numerous cells in blood are:

4. The main function of the red blood cells is:

5. How would you tell a white cell from a red cell when looking at them through a microscope? (Give at least 2 differences)

6. How does the blood help fight invasion by bacteria and viruses?

7. What would happen to blood if there were no platelets?

Test Yourself Answers

1. Via what vessel does blood enter the heart from the body?
2. Blood passing through the right atrioventricular valve passes into which chamber of the heart?
3. What is the function of the pulmonary valve?
4. Does the pulmonary artery carry deoxygenated or oxygenated blood?
5. The walls of the heart are made of what tissue?
6. Does the aorta carry deoxygenated or oxygenated blood?

Test Yourself Answers

1. Give 2 differences between arteries and veins

2. What is systole?

3. Circle the correct answer below.

   Blood flows by this route through the blood vessels of the body.

   a) heart | veins | capillaries | arteries | heart b) heart | arteries | capillaries | veins | heart c) heart | veins | arteries | capillaries | heart

   d) heart | capillaries | arteries | veins | heart

4. Name the vessel that carries blood:

   from the heart to the main organs of the body:

   from the aorta to the brain:

   from the aorta to the kidneys:

   from the intestines to the liver:

   from the aorta to the heart muscle:

Test Yourself Answers

8.6 Websites

Wikipedia has good information of red and white blood cells.
http://en.wikipedia.org/wiki/Red_blood_cell Red blood cells
http://en.wikipedia.org/wiki/White_blood_cell White blood cells

8.7 Glossary

Link to Glossary